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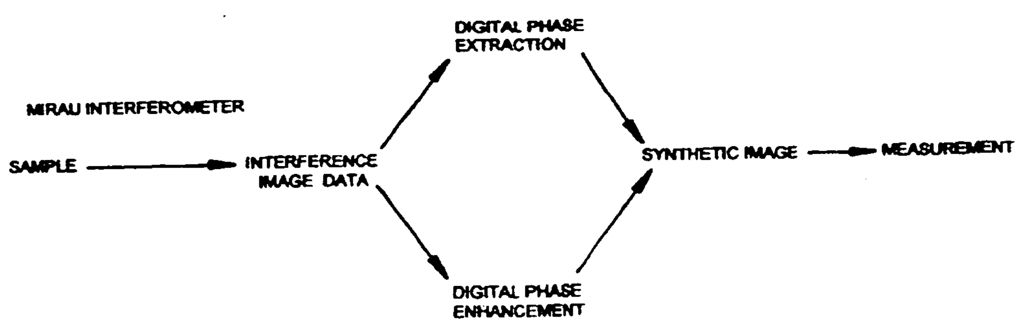

(57) Abstract

The invention relates to a method for inspecting and measuring the degree of alignment between a first pattern or mark provided on a first surface and a second pattern or mark provided on a second surface which second surface is aligned with respect to said first surface wherein the method involves the use of interference image data which is generated using a Mireau Interferometer.

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IMAGE ENHANCEMENT USING INTERFEROMETRY

The invention relates to a method and apparatus for the inspection and ideally measurement of surface patterns particularly, but not exclusively, in instances where surface topography may be low or the surface is planarised.

The method and apparatus of the invention is particularly suited to the field of computerised optical tools such as metrology tools and so to the automated inspection and measurement of patterns on layers in a semiconductor multilayer wafer fabrication process.

In a semiconductor multilayer wafer fabrication process, there is a repeated step involving the printing of a new layer on top of a previous reference layer through a process of photolithography. Technology requirements make ever increasing demands on the degree of accuracy to which these layers should be aligned. The error in alignment is known as overlay error or misregistration error. This overlay error is carefully monitored. Some manual monitoring techniques exist, but in recent years this has become mostly an automated process performed by machines known as Overlay Metrology Tools.

An overlay metrology tool operates on an overlay target which often comprises two rectilinear marks. Typically, the bigger mark which is called the Outer, is printed as part of the selected reference layer. The smaller mark, called the Inner, is then printed inside the outer as part of the new layer that is being superimposed. A typical overlay mark is illustrated in Figure 1.

The tool determines the overlay error by first determining the centre point of each mark, and then computing the distance between these two centre points.

Optical inspection of small overlay marks or patterns has been performed using imaging apparatus of a conventional nature such as a microscope in combination with electronic image processing. In this way images have been viewed in order to determine the nature of their alignment. However, particularly in the semiconductor industry, chemical and mechanical processes are now being used to polish and so planarize wafer surfaces and these techniques undesirably degrade the optical appearance of the mark on the wafer surface. Thus using conventional apparatus it is difficult to view the marks and thus make the appropriate measurements. Moreover the polishing process itself may introduce asymmetries into the appearance of the mark that undesirably distort any measurements of overlay error that are made.

Figure 1 shows two camera images of overlay marks, each consisting of a plurality of pixels or image points with various intensities arranged in rows and columns. The right hand side of the Figure shows an image in which the contrast between the two overlay marks and the wafer substrate is relatively high and which is therefore suitable for conventional analysis. The left hand side of the Figure shows an image where the contrast between the outer mark and the wafer substrate has been degraded as a consequence of chemical and/or mechanical processing. It is of note that instances may occur where more than one mark is degraded and in these instances an image would be presented where both marks were difficult to distinguish.

Conventionally, the first step in measuring the overlay error represented by an image such as those in Figure 1 is to take one or more lines passing

through the selected mark. Ideally such lines are selected having regard to the geometry of the mark. For example, where a rectangular mark is used such lines are typically vertical and/or horizontal and lie along rows or columns in the image. The line gives rise to an image cross-section profile where the displacement at each point in the profile represents the image signal level in each corresponding pixel along said line.

In an alternative example, where a non-rectangular mark is used such lines are either vertical and/or horizontal or at an angle thereto.

Referring to Figure 1 it can be seen that two cross-section profiles 1 and 2 are provided. Towards the left hand side of the Figure the outer mark is represented with relatively low image contrast and therefore the corresponding displacements A are relatively shallow. Towards the right hand side of Figure 1 the outer mark provides a relatively strong signal. Accordingly the signal data in each image point is relatively strong and therefore displacements H corresponding to the two outer vertical lines of the outer mark are relatively large.

Conventionally, edge detection techniques are applied to locate the centres of the marks in the profiles. The edges are separately determined for each mark in each axis. The centre of each mark is then determined as the midpoint between opposite edges in the profile. The overlay measurement result is determined as the distance between the centre points of the two marks.

Where the image is made up of horizontal and vertical lines only, it is possible to take similarly looking cross sections of it at many places rather than just one. When this is done, several measurements estimates are

obtained and are later averaged or processed in some other statistical manner to improve the precision of the overall measurement.

A problem in the measurement process may occur as a result of poor contrast in the cross sections of either mark, for example where wafer fabrication processes, such as the chemical and/or mechanical polishing (CMP) process or other planarization processes, have degraded the topography and hence the contrast and of the optical image of overlay marks.

Under these circumstances, the precision of overlay measurement of such marks, by means of metrology tools equipped with conventional optics, may degrade considerably. To overcome this, optical systems that are sensitive to variations in the phase as well as the amplitude of the target illumination may be used. Interferometers are such systems. The Linnik interferometer is one prior art implementation which has been used for that purpose and it is shown in Figure 2.

A comprehensive description of the use of a Linnik interferometer for measuring an overlay misregistration during semiconductor wafer fabrication is described in US patent 5,438,413 and therefore will not be discussed in great detail herein. However, it is of note that the use of the Linnik interferometer is characterised by the use of an interference optical system that includes a sample channel and, distinct therefrom, a reference channel. As can be seen from Figure 2 the two channels are typically positioned perpendicular with respect to each other and a beam splitter is used to direct wave energy such as light along each channel. A camera is provided to detect the magnitude of mutual coherence between wave energy reflected from the sample and wave energy reflected from the reference mirror. The

magnitude of this mutual coherence data is then used to generate a synthetic image of the sample. This synthetic image effectively enhances differences between parts of the sample surface and so enhances the contrast of the image. Figure 3 shows the intensity response of the interference signal along the Z axis, which is dependent on the phase of the light reflected from the sample. It can be seen that the intensity varies much more rapidly (see graph marked A of Figure 3) than that of an ordinary bright field microscope, sensitive to the amplitude (see graph marked C of Figure 3). As a consequence, the interference signal is much more sensitive to small height variations in the sample.

However, there are at least two significant disadvantages of the Linnik interferometer. The first concerns the use of two objectives. As clearly seen in Figure 2 both a sample and a reference objective is required in order to use the Linnik interferometer. These two objectives must be very well matched in terms of their optical qualities. This presents difficulties in terms of manufacturing the two objectives and can, if the two objectives are not well matched, result in a degradation of the system. A further disadvantage concerns the need to finely align the two objectives with respect to the diagonal beam splitter in an asymmetrical and difficult to align fashion. Such fine matching and alignment of the two objectives vis a vis the beam splitter makes the production of a Linnik interferometer complicated, time-consuming and costly. A further disadvantage associated with the Linnik interferometer concerns the requirement for long-path lengths of the image and referenced paths. This results in large fluctuations in these paths as a result of vibrations, thermal changes and other factors all of which contribute to degrade the quality of the obtained interference signals.

It can therefore be seen that there is a need to provide a means for improving the visualisation of relatively flattened sample surfaces, but based on interferometry in order to obtain the advantages associated with the sensitivity of an interference signal to small height variations in a sample.

Other interferometers are known such as the Mirau interferometer. The Mirau interferometer consists of a special objective fitted to an otherwise standard bright-field metallurgical microscope. This objective has a plate beam splitter after its final element that allows the camera to simultaneously focus on the surface of the wafer and a small plane mirror spot deposited on a transparent surface placed equidistantly above the beam splitter. The Mirau interferometer is illustrated in Figure 4. Constructive and destructive interference between these two images occurs, depending on the exact phase of the signal and reference rays. By scanning the wafer surface slowly through focus and observing the variations in brightness of each pixel in the image, it is possible to create a synthetic image demonstrating much greater contrast variations corresponding to topography variations on the wafer, than would be possible with a bright-field microscope. Such an image can consequently be used for overlay metrology, defect inspection, and critical dimension measurement, producing superior results.

The Mirau interferometer requires that a plane beam splitter be placed after the finite element of the objective, and thus that the objective needs to be positioned relatively farther from the sample to allow room for this beam splitter. It follows that the Numerical Aperture (NA) of the Mirau objective, affected by this distance, cannot be as large a figure as that achievable with the Linnik. Since the resolution of the objective is proportional to its Numerical Aperture, it follows that the resolution of the Mirau will be

somewhat smaller. Given the need in bright field imaging to maximise resolution in order to visualise relatively small features, including low topography features such as those produced by chemical and or mechanical polishing of semiconductor waters, the Mirau has therefore been disregarded by those skilled in the art. Those who have considered Mirau interferometry have suggested the use of a very thin pellicle beam splitter to allow objectives with a high Numerical Aperture to be constructed. However, such thin pellicles are much more prone to give rise to disturbances in the quality of the image, such as those that may be created by vibrations of the pellicle and are therefore disregarded by those skilled in the art.

Surprisingly, we have discovered that for the purpose of overlay metrology and in particular for the measurement of low topography features there is actually a benefit in a reduced numerical aperture. The quality of an overlay metrology tool is often judged by its associated Tool-Induced-Shift (TIS). TIS is a figure by which the measurement results deviates from its true value. Due to the ever increasing demand for higher accuracy metrology tools, the TIS value is of major importance in evaluating the overall quality of the tool. In employing an objective with relatively low Numerical Aperture we have been able to produce lower TIS tools with greater accuracy and precision of the measurement results.

Thus we have discovered that low numerical aperture can be used to advantage, and thus contrary to the prejudices existing in the art, a Mirau interferometer can be used to advantage for the measurement of low contrast overlay targets.

It is therefore an object of the invention to provide an apparatus for the inspection and/or measurement of a pattern or mark on a relatively planarised surface which makes use of a Mirau interferometer.

It is yet a further object of the invention to provide a method for inspecting and/or measuring a pattern or mark on a relatively planarised surface which method employs the use of interference techniques and more specifically interference techniques which employ the use of a single wave energy channel.

It is yet a further object of the invention to provide a metrology tool including a Mirau interferometer and also to use said Mirau interferometer in the metrology tool.

It is yet a further object of the invention to provide a method for enhancing data provided by a metrology tool including a Mirau interferometer.

According to a first aspect of the invention there is therefore provided a method of inspecting and measuring the degree of alignment between a first pattern or mark provided on a first surface and a second pattern or mark provided on a second surface which second surface is aligned with respect to said first surface so as to determine the amount of displacement error in said alignment comprising;

(i) using an interference optical system characterised in that it includes a single channel through which wave energy from a sample and wave energy from a reference passes prior to interference between same so as to provide interference image data of said sample as a result of

mutual coherence between wave energy reflected from at least a part of said sample surface and wave energy reflected from at least a part of said reference surface;

(ii) using said interference image data to generate at least one synthetic image of said sample; and

(iii) using the said synthetic image to determine the degree of displacement error in said alignment of said first relative to said second pattern or mark.

In a preferred embodiment of the invention said first and second patterns or marks are ideally aligned so as to be concentric such that the synthetic image is examined in order to determine the concentric nature of the said first and second marks and more specifically to determine whether the centre points of said first and second marks are perfectly aligned.

In the preferred embodiment of the invention said interference optical system comprises a Mirau interferometer and thus said sample and reference wave energy travels in a single channel typically perpendicular to the plane of the sample surface.

More preferably still said apparatus consists of a metallurgical microscope and a Mirau interferometer and more specifically a standard bright-field metallurgical microscope and a Mirau interferometer.

More preferably further still said method includes digital phase extraction and/or enhancement of said image data as described hereinafter.

According to a second aspect of the invention there is provided an apparatus for inspecting and measuring the degree of alignment between a first pattern or mark provided on a first surface and a second pattern or mark provided on a second surface, which second surface is overlain and aligned with respect to said first surface, so as to determine the amount of displacement error in said alignment comprising: an overlay metrology tool including an interference optical system characterised in that said system includes a single channel through which wave energy from a sample and wave energy from a reference passes prior to interference between same so as to provide interference image data of said sample as a result of mutual coherence between wave energy reflected from at least a part of said sample surface and wave energy reflected from at least a part of said reference surface and imaging means for converting said interference image data into a synthetic image of said sample.

In a preferred embodiment of the invention said interference optical system comprises a Mirau interferometer.

To reduce the hazard of microphonic vibration in the beam splitter pellicle of conventional Mirau objectives we have chosen to use a thicker beam splitter plate together with an objective specifically designed to compensate for the spherical aberration that these would otherwise produce. We term one example of this sort of objective the "Hammond objective" which is described comprehensively in our copending patent application no.

According to a yet further aspect of the invention there is provided the use of a Mirau interferometer in an overlay metrology tool.

According to a yet further aspect of the invention there is provided a method as herein described for digital phase extraction and/or enhancement of interference image data provided by the use of a Mirau objective in a metrology tool.

Digital phase extraction is undertaken having regard to the following explanation and equations.

As the image of the wafer is slowly scanned through focus, each of the pixels in the image will undergo a cyclical change in intensity as constructive and destructive interference with the reference beam occurs. If the intensity of a given pixel is plotted against focus (Z-axis), the resulting graph will look like that of Figure 3.

This intensity waveform is modelled using the equation;

$$I_{(z)} = A_{(z)} \cdot \cos(\omega \cdot z + \phi_0)$$

Where I is the intensity, A is the amplitude function of the signal and ω is the characteristic frequency of the interferometer given by $\omega = 2\pi/\lambda$, where λ is the period of the interference in Z. ϕ_0 is the initial value of the phase at location zero.

The Phase of the interference intensity, is the argument of the cosine function $\omega \cdot z+\phi_0$. It is linear in Z. This means that when focusing on a sample, the phase of the intensity signal at each point of the sample image, is proportional to the topography of the sample at that point. Creating a synthetic image each pixel of which reflecting the phase value at that pixel,

will therefore produce a topography map of the sample. Such a map image can be used for metrology purposes.

For the phase to be extracted, the intensity level at each point must be sampled at constant intervals along the Z axis. Extracting the phase and amplitude at every point can ideally be performed in the Fourier domain, by taking the Fourier Transform of the Z samples at each image point.

This process also allows to determine the best focus position for the image. It is simply the location in Z where the amplitude is the highest.

According to a yet further aspect of the invention there is provided a method of digital phase extraction of interference image data provided by an interferometer metrology tool which method comprises measuring the intensity of each interference image data point having regard to the following equation;

$$I_{(z)} = A_{(z)} \cdot \cos(\omega \cdot z + \phi_0)$$

where I is the intensity, A is the amplitude function of the signal and ω is the characteristic frequency of the interferometer given by $\omega = 2\pi/\lambda$, where λ is the period of the interference in Z. ϕ_0 is the initial value of the phase at location zero.

According to a yet further aspect of the invention there is provided a method for creating a synthetic image of a sample using interference image data of said sample which method involves providing interference image data relating to said sample so as to provide a synthetic interference image of said sample

made up of a plurality of pixels and then measuring selected pixel intensities of said image using the following equation;

$$I_{(z)} = A_{(z)} \cdot \cos(\omega \cdot z + \phi_0)$$

where I is the intensity, A is the amplitude function of the signal and ω is the characteristic frequency of the interferometer given by $\omega = 2\pi/\lambda$, where λ is the period of the interference in Z. ϕ_0 is the initial value of the phase at location zero.

Although in certain embodiments of the invention we use numerical phase extraction in order to recover data the phase can only be recovered in the range 0 to π, or $-\pi$ to π as shown in figure 5. That means that unlike the original phase which is linear in Z, the extracted phase will only be linear in segments of Z. This implies that in general, an accurate topography image of the sample cannot be created, unless the topography changes are very small and the Z position is determined to a great degree of accuracy, so that the entire topography can be fitted in one segment.

In order to overcome the above difficulties we have provided a new method for providing a synthetic image using the metrology tool of the invention which method uses digital phase enhancement of interference image data provided by the use of a Mirau objective in a metrology tool. We term this the "Yanowitz Phase Enhancement Method".

Digital or "Yanowitz" phase enhancement is undertaken having regard to the following explanations.

At a specific location in Z, there will be a difference in intensities between adjacent pixels, if there is a variation in topography of the sample between them. The sign and magnitude of this difference, will depend on the particular phase of the interference intensity at that specific Z location. This is demonstrated in Figure 6. We rectify the difference by taking its absolute value, however, which only makes the magnitude vary. Based on the fact that the envelope (see Figure 3.) does not change much near the focus location (which is especially true for cases of smaller NA, like the one we are using), we average that difference, in small increments, over an entire wave cycle, or multiples of it, to produce a value that is independent of Z position, but whose magnitude is representative of the phase difference between adjacent pixels. This is shown in Figure 7. Doing that to all the pixels in the image, produces a new synthetic and enhanced image.

A further advantage of this new method relative to the elaborate phase extraction is that it is much simpler in terms of numerical computations and therefore much faster to perform. Better measurement precision can be obtained by using this method since the straightforward difference operation used to derive the synthetic image is much less sensitive to the noisy and fluctuating signal which is characteristic of low contrast images, than the more elaborate phase extraction operation.

According to a yet further aspect of the invention there is therefore provided a method of digital phase enhancement of interference image data provided by an interferometer metrology tool which method comprises measuring the intensity of interference image data at selected pixel locations; modifying the intensity difference between said pixels; and then averaging said modified difference over at least one wave cycle to produce an intensity difference that

is independent of Z position but representative of the phase difference between adjacent pixels.

In a preferred method of the invention said modification involves rectifying said intensity difference by taking an absolute value.

In a preferred method of the invention a first pixel is compared with a second pixel positioned at least one pixel remote therefrom, thus neighbouring pixels are typically not compared rather a pixel designated 1 would be compared with a pixel designated 3 or greater, regardless of direction.

According to a yet further aspect of the invention there is provided a method for creating a synthetic image of a sample using interference image data of said sample which method involves providing interference image data relating to said sample and then enhancing said data by measuring the intensity of interference image data at selected pixel locations; modifying the intensity difference between said pixels; and then averaging said modified difference over at least one wave cycle to produce an intensity difference that is independent of Z position but representative of the phase difference between adjacent pixels.

In a preferred method of the invention said modification involves rectifying said intensity difference by taking an absolute value.

An embodiment of the invention is described by way of example only with reference to the following figures wherein:

Figure 1 is an illustration of typical Bar-in-Bar type overlay marks and

respective horizontal intensity profiles. Right: good contrast inner and outer marks. Left: case of low contrast outer mark;

Figure 2 shows an optical layout of the Linnik interferometer;

Figure 3 shows characteristic intensity response of white light interference along the Z axis. The intensity varies much more rapidly than its envelope which, in turn, varies more rapidly than the bright-field intensity would.

Figure 4 shows an optical lay out of the Mirau interferometer;

Figure 5 shows the phase of the signal of Figure 3, as extracted by means of numerical computations. Unlike the original phase, the extracted phase is triangular and varies between 0 to π (it can also be extracted to the range $-\pi$ to π, in which case it will have a saw-tooth form with discontinuities at the boundaries).

Figure 6 shows the intensity variation of two adjacent pixels differing slightly in topography (and hence phase), along two periods in Z. The third (smaller) signal shows the difference in intensities. It also has the same period.

Figure 7 shows the rectified difference signal and its average (the horizontal line) over two periods.

Figure 8 is a flow chart showing the method of the invention.

The invention therefore essentially concerns the use of interference techniques to undertake overlay measurements in the semiconductor industry. More

specifically, the invention concerns the use of an Mirau interferometer to undertake such measurements and thus, as shown in Figure 8, the invention concerns the provision of interference image data relating to a sample, by way of using a Mirau interferometer, and the subsequent analysis of said data either by digital phase extraction and/or digital phase enhancement so as to provide a synthetic image of said sample. Once the synthetic image has been provided one can then use this to determine the degree of displacement error between a first pattern or mark provided on a first surface and a second pattern or mark provided on a second surface when undertaking metrology measurements.

Thus we provide a novel approach to obtaining interference image data in overlay metrology tools and also a novel way of processing the data so as to provide for an enhanced synthetic image which facilitates the determination of overlay measurements.

CLAIMS

1. A method of inspecting and measuring the degree of alignment between a first pattern or mark provided on a first surface and a second pattern or mark provided on a second surface which second surface is aligned with respect to said first surface so as to determine the amount of displacement error in said alignment comprising;

i) using an interference optical system characterised in that it includes a single channel through which wave energy from a sample and wave energy from a wave reference passes prior to interference between same so as to provide interference image data of said sample as a result of mutual coherence between wave energy reflected from at least a part of said sample surface and wave energy reflected from at least a part of said reference surface;

ii) using said interference image data to generate at least one synthetic image of said sample; and

iii) using the said synthetic image to determine the degree of displacement error in said alignment of said first relative to said second pattern or mark.

2. A method according to Claim 1 wherein said first and second patterns or marks are ideally aligned so as to be concentric such that the synthetic image is examined in order to determine the concentric nature of the said first and second marks.

3. A method according to Claim 2 wherein said examination is undertaken to determine whether the centre points of said first and second marks are perfectly aligned.

4. A method according to Claim 1, 2 or 3 wherein said interference optical system comprises a Mireau interferometer and thus said sample and reference wave energy travels in a single channel typically perpendicular to the plane of the sample surface.

5. A method according to any preceding claim further including digital phase extraction and/or enhancement of said image data.

6. A method according to Claim 5 wherein digital phase extraction of interference image data provided by an interferometer metrology tool comprises measuring the intensity of each interference image data point having regard to the following equation

$$I_{(Z)}=A_{(Z)}.\cos\,(w.Z + \phi_o)$$

where I is the intensity, A is the amplitude function of the signal and w is the characteristic frequency of the interferometer given by $w = 2\pi/$, where is the period of the interference in Z. ϕ_o is the initial value of the phase at location zero.

7. A method according to any preceding claim wherein a synthetic image of a sample is created using interference image data of said sample and the method involves providing interference image data relating to said sample so as to provide a synthetic interference image of said sample made up of a

plurality of pixels and then measuring selected pixel intensities of said image using the following equations;

$$I_{(Z)}=A_{(Z)}.\cos\ (w.Z + \phi_o)$$

where I is the intensity, A is the amplitude function of the signal and w is the characteristic frequency of the interferometer given by $w = 2\pi/$, where is the period of the interference in Z. ϕ_o is the initial value of the phase at location zero.

8. A method according to Claim 5 wherein digital phase enhancement of interference image data is provided by an interferometer metrology tool by a method which comprises measuring the intensity of interference image data at selected pixel locations; modifying the intensity difference between said pixels; and then averaging said modified difference over at least one wave cycle to produce an intensity difference that is independent of Z position but representative of the phase difference between adjacent pixels.

9. A method according to Claim 8 wherein said modification involves rectifying said intensity difference by taking an absolute value.

10. A method according to Claim 8 or Claim 9 wherein a first pixel is compared with a second pixel positioned at least one pixel remote therefrom.

11. A method according to any preceding claim for creating a synthetic image of a sample using interference image data of said sample which method involves providing interference image data relating to said sample and then enhancing said data by measuring the intensity of interference image

data at selected pixel locations; modifying the intensity difference between said pixels; and then averaging said modifying difference over at least one wave cycle to produce an intensity difference that is independent of Z position but representative of the phase difference between adjacent pixels.

12. A method according to Claim 11 wherein said modification involves rectifying said intensity difference by taking an absolute value.

13. Apparatus for inspecting and measuring the degree of alignment between a first pattern or mark provided on a first surface and a second pattern or mark provided on a second surface, which second surface is overlain and aligned with respect to said first surface, so as to determine the amount of displacement error in said alignment comprising:

an overlay metrology tool including an interference optical system characterised in that said system includes a single channel through which wave energy from a sample and wave energy from a reference passes prior to interference between same so as to provide interference image data of said sample as a result of mutual coherence between wave energy reflected from at least a part of said sample surface and wave energy reflected from at least a part of said reference surface and imaging means for converting said interference image data into a synthetic image of said sample.

14. Apparatus according to Claim 13 wherein said interference optical system comprises a Mireau interferometer.

15. Apparatus according to Claim 13 or Claim 14 wherein said apparatus consists of a metallurgical microscope and a Mireau interferometer and more

specifically a standard bright-field metallurgical microscope and a Mireau interferometer.

AMENDED CLAIMS

[received by the International Bureau on 15 September 1997 (15.09.97); original claims 1-15 replaced by amended claims 1-13 (5 pages)]

1. A method of inspecting and measuring the degree of alignment between a first pattern or mark provided on a first surface and a second pattern or mark provided on a second surface which second surface is aligned with respect to said first surface so as to determine the amount of displacement error in said alignment comprising;

i) using an interference optical system comprising a Mirau interferometer, characterised in that it includes a single channel perpendicular to the plane of a sample surface through which wave energy from the sample and wave energy from a wave reference passes prior to interference between same so as to provide interference image data of said sample as a result of mutual coherence between wave energy reflected from at least a part of said sample surface and wave energy reflected from at least a part of said reference surface;

ii) using said interference image data to generate at least one synthetic image of said sample; and

iii) using the said synthetic image to determine the degree of displacement error in said alignment of said first relative to said second pattern or mark;

further characterised in that the Mirau interferometer comprises a conventional thick beamsplitter plate together with an objective

adapted to compensate for spherical aberration otherwise introduced by the beam splitter plate.

2. A method according to Claim 1 wherein said first and second patterns or marks are ideally aligned so as to be concentric such that the synthetic image is examined in order to determine the concentric nature of the said first and second marks.

3. A method according to Claim 2 wherein said examination is undertaken to determine whether the centre points of said first and second marks are perfectly aligned.

4. A method according to any preceding claim further including digital phase extraction and/or enhancement of said image data.

5. A method according to Claim 4 wherein digital phase extraction of interference image data provided by an interferometer metrology tool comprises measuring the intensity of each interference image data point having regard to the following equation

$$I_{(Z)}=A_{(Z)}.\cos(w.Z+\phi_o)$$

where I is the intensity, A is the amplitude function of the signal and w is the characteristic frequency of the interferometer given by $w = 2\lambda$, where λ is the period of the interference in Z, ϕ_o is the initial value of the phase at location zero.

6. A method according to any preceding claim wherein a synthetic image of a sample is created using interference image data of said sample and the method involves providing interference image data relating to said sample so as to provide a synthetic interference image of said sample made up of a plurality of pixels and then measuring selected pixel intensities of said image using the following equations;

$$I_{(Z)}=A_{(Z)}.\cos(w.Z+\phi_o)$$

where I is the intensity, A is the amplitude function of the signal and w is the characteristic frequency of the interferometer given by $w = 2/\lambda$, where λ is the period of the interference in Z, ϕ_o is the initial value of the phase at location zero.

7. A method according to Claim 4 wherein digital phase enhancement of interference image data is provided by an interferometer metrology tool by a method which comprises measuring the intensity of interference image data at selected pixel locations; modifying the intensity difference between said pixels; and then averaging said modified difference over at least one wave cycle to produce an intensity difference that is independent of Z position but representative of the phase difference between adjacent pixels.

8. A method according to Claim 7 wherein said modification involves rectifying said intensity difference by taking an absolute value.

9. A method according to Claim 7 or Claim 8 wherein a first pixel is compared with a second pixel positioned at least one pixel remote therefrom.

10. A method according to any preceding claim for creating a synthetic image of a sample using interference image data of said sample which method involves providing interference image data relating to said sample and then enhancing said data by measuring the intensity of interference image data at selected pixel locations; modifying the intensity difference between said pixels; and then averaging said modifying difference over at least one wave cycle to produce an intensity difference that is independent of Z position but representative of the phase difference between adjacent pixels.

11. A method according to Claim 10 wherein said modification involves rectifying said intensity difference by taking an absolute value.

12. Apparatus for inspecting and measuring the degree of alignment between a first pattern or mark provided on a first surface and a second pattern or mark provided on a second surface, which second surface is overlain and aligned with respect to said first surface, so as to determine the amount of displacement error in said alignment comprising:

an overlay metrology tool including an interference optical system comprising a Mirau interferometer characterised in that said system includes a single channel perpendicular to the plane of a sample surface through which wave energy from the sample and wave energy from a reference passes prior to interference between same so as to provide interference image data of said sample as a result of mutual coherence between wave energy reflected from at least a part of said sample surface and wave energy reflected from at least a part of said reference surface and imaging means for converting said interference

image data into a synthetic image of said sample;

further characterised in that the Mirau interferometer comprises a conventional thick beam splitter plate together with an objective adapted to compensate for spherical aberration otherwise introduced by the beam splitter plate.

13. Apparatus according to Claim 12 wherein said apparatus consists of a metallurgical microscope and a Mirau interferometer and more specifically a standard bright-field metallurgical microscope and a Mirau interferometer.

STATEMENT UNDER ARTICLE 19

Claims 1 and 14 are amended with reference to the claims and description to more clearly define the method and apparatus for which it is desired to obtain protection as follows.

The method and apparatus relates to method and apparatus for metrology employing a conventional Mirau interferometer, which may be considered to be conventional, specifically in respect of the thickness of the beam splitter plate, but which comprises means to compensate for spherical aberration which such a thick plate may be expected to produce, said means comprising a compensating objective.

In this regard, we submit that the prior art literature which relates to none conventional Mirau interferometer's or to specific means of processing interference image data obtained from such Mirau interferometers are therefore not relevant to the method and apparatus at the present invention.

Further amendments to the claims and description are in respect of formal amendment.

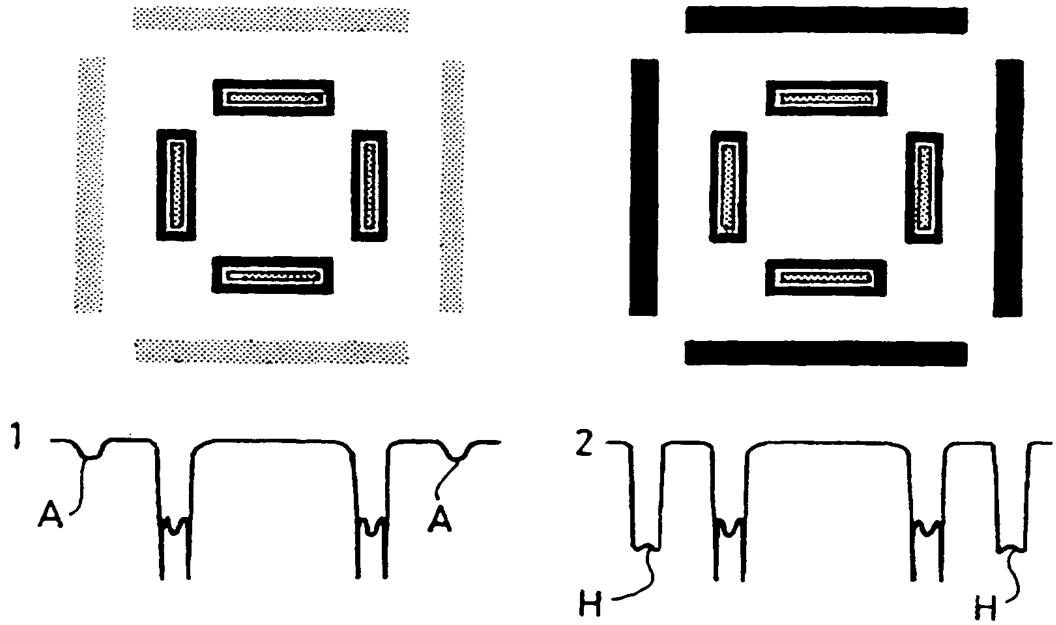
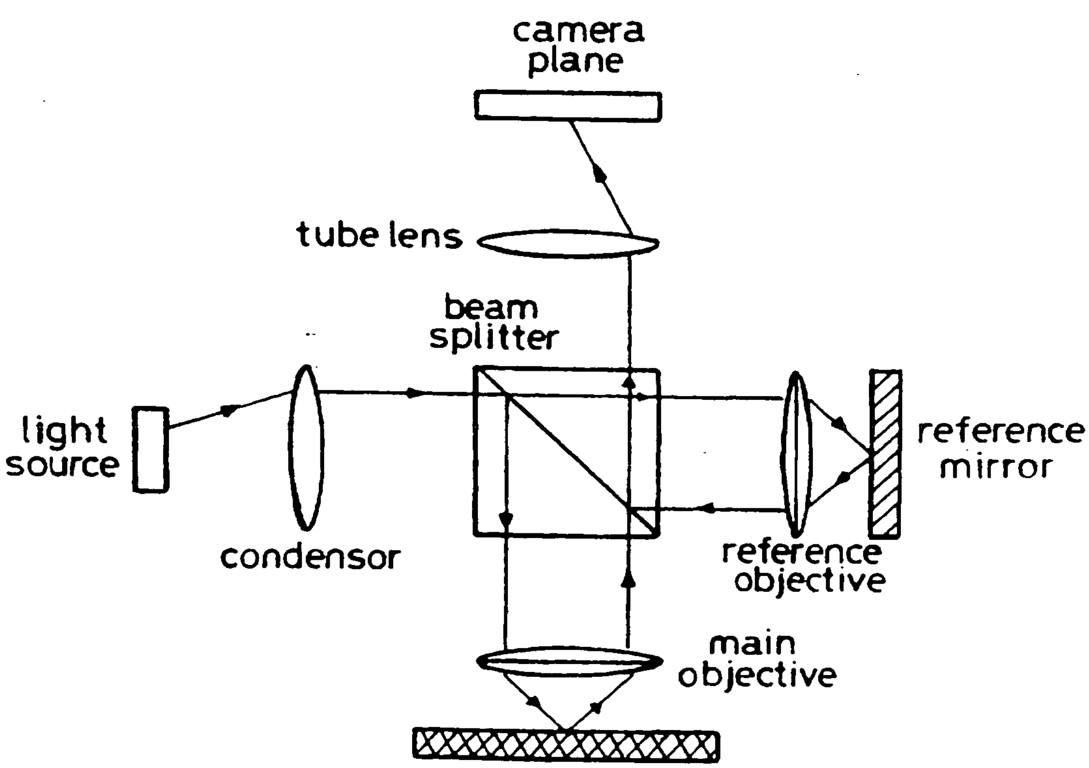

1
A
A
2
H
H

Fig. 1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tube lens
beam splitter
light source
condensor
reference mirror
reference objective
main objective
sample

Fig. 2

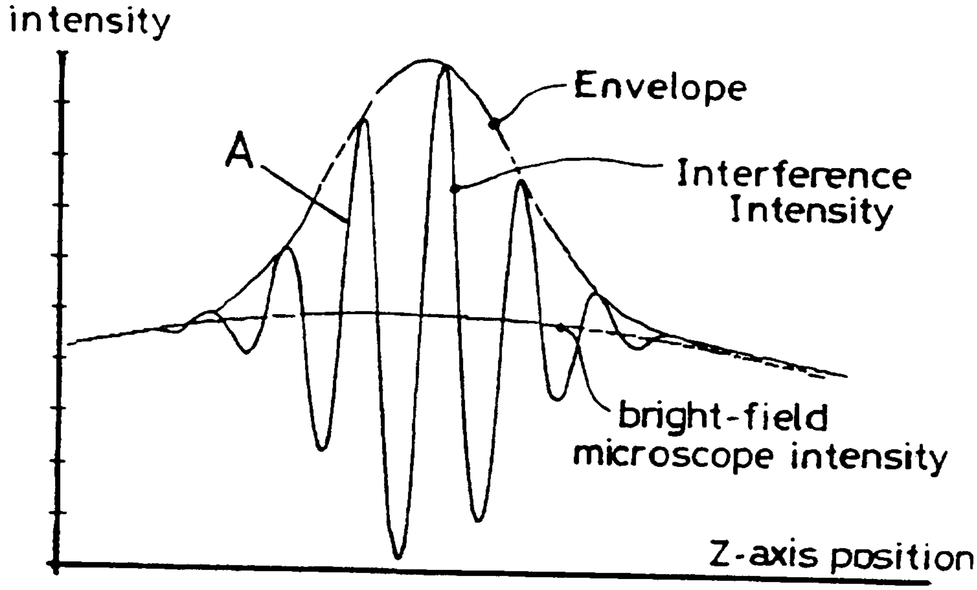
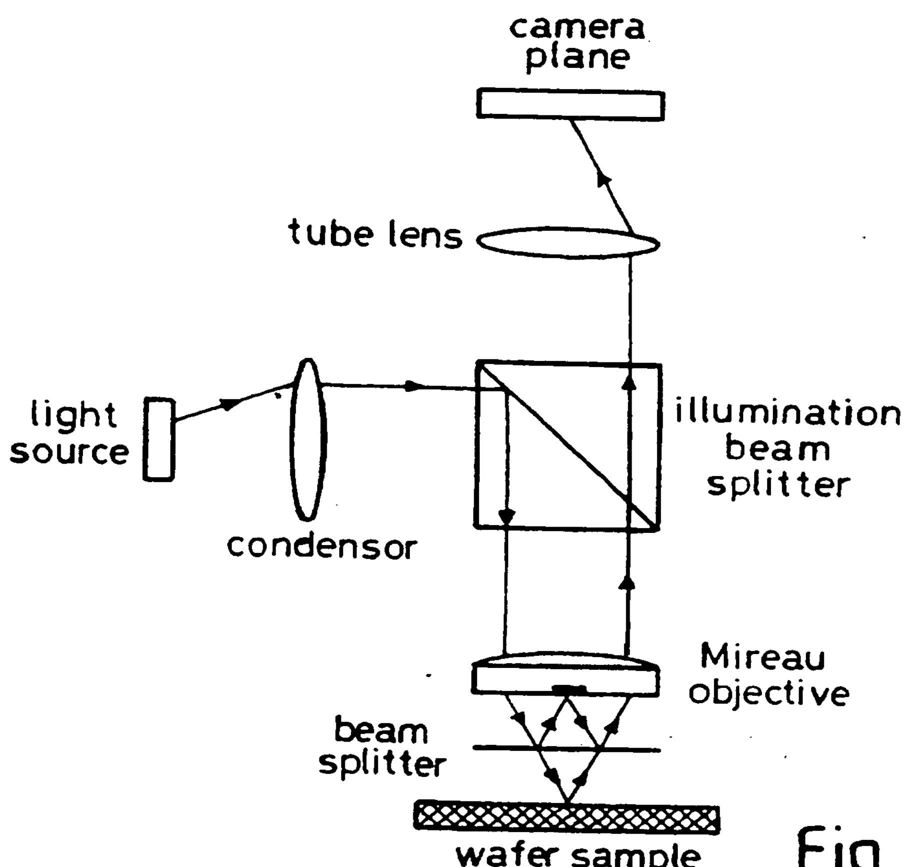

intensity
Envelope
A
Interference Intensity
bright-field microscope intensity
Z-axis position

Fig. 3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tube lens
light source
condensor
illumination beam splitter
Mireau objective
beam splitter
wafer sample

Fig. 4

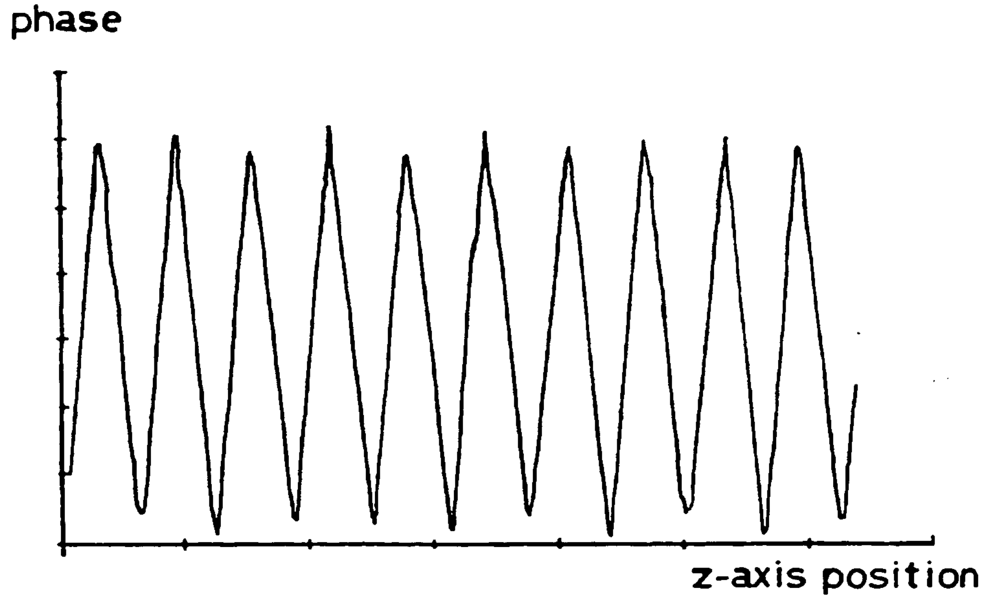

Fig. 5

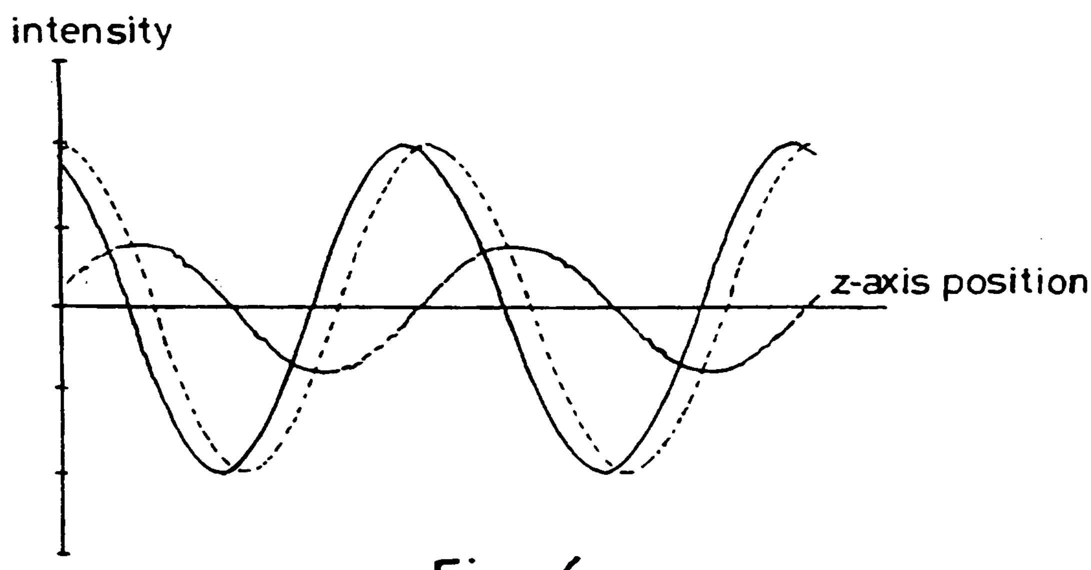

Fig. 6

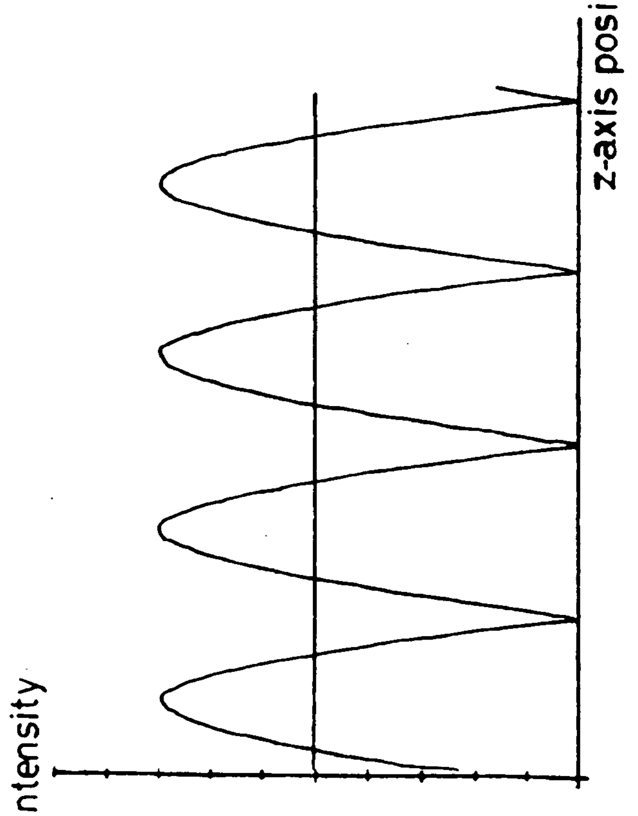
intensity
z-axis position

Fig. 7

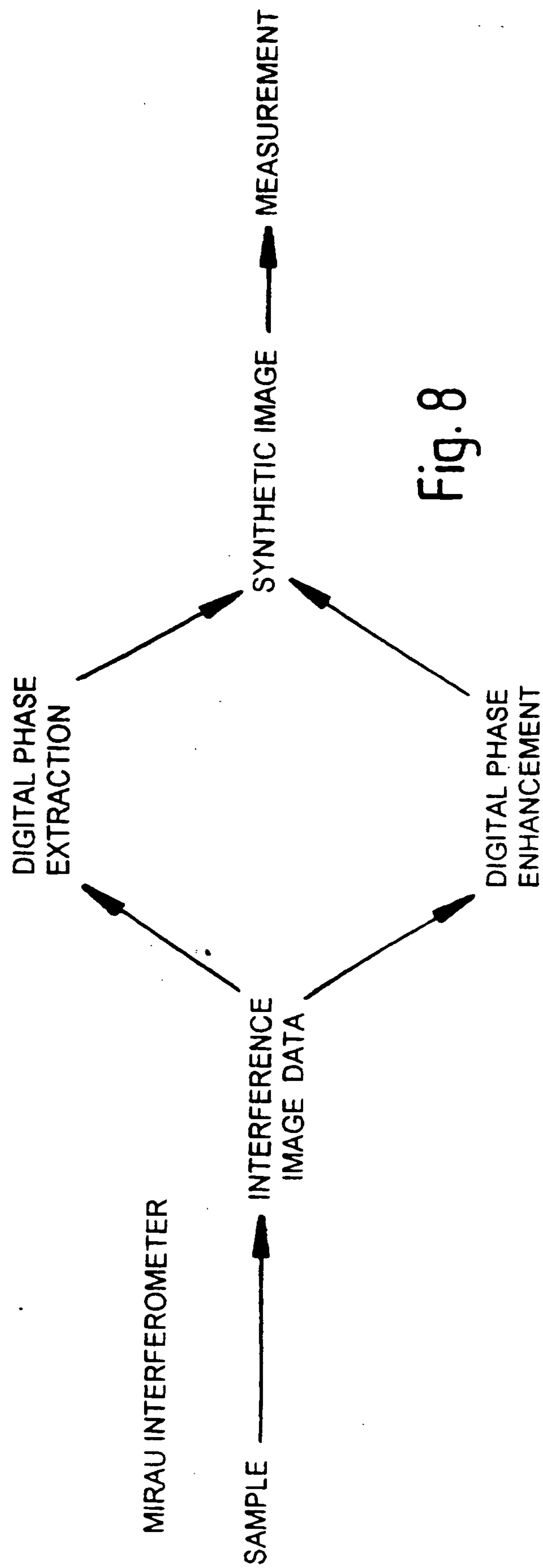
MIRAU INTERFEROMETER
SAMPLE
INTERFERENCE IMAGE DATA
DIGITAL PHASE EXTRACTION
DIGITAL PHASE ENHANCEMENT
SYNTHETIC IMAGE
MEASUREMENT

Fig. 8

INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/GB 97/01006

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G03F7/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 375 175 A (KINO GORDON S ET AL) 20 December 1994 see column 1, line 1 - column 2, line 62 see column 7, line 18 - line 43 see figures 1-3,11 ---	1-5, 13-15
X	EP 0 562 133 A (SANDSTROEM ERLAND TORBJOERN) 29 September 1993 see page 2, line 1 - line 21 see page 6, line 1 - line 44 see figure 4	1,4,5, 13-15
Y	---	2,3
Y	US 5 438 413 A (MAZOR ISAAC ET AL) 1 August 1995 cited in the application see column 4, line 18 - column 6, line 35 see figures 5-12 ---	2,3

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
14 July 1997	18.07.97
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Authorized officer Heryet, C

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INTERNATIONAL SEARCH REPORT

Inter   nal Application No
PCT/GB 97/01006

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 073 018 A (KINO GORDON S ET AL) 17 December 1991 see column 1, line 1 - column 5, line 2 see column 7, line 66 - column 8, line 8 see figures 1,2 ---	13-15
X	JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY: PART B, vol. 8, no. 6, 1 November 1990, pages 1652-1656, XP000169227 KINO G S: "SCANNING OPTICAL MICROSCOPY" see abstract see page 1654, right-hand column, paragraph 3 - page 1656, left-hand column see figures 5-7 ---	13-15
E	US 5 633 714 A (NYYSSONEN DIANA) 27 May 1997 see column 4, line 1 - column 7, line 18 see figures 1A-1C -----	1,4,5, 13-15

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INTERNATIONAL SEARCH REPORT

..iformation on patent family members

Inter ial Application No
PCT/GB 97/01006

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		US 5440426 A	08-08-95
US 5438413 A	01-08-95	JP 7006948 A	10-01-95
US 5073018 A	17-12-91	WO 9105218 A	18-04-91
US 5633714 A	27-05-97	NONE	